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GEOLOGY.—*The Pleistocene Horry clay and Pamlico formation near Myrtle Beach, S. C.*[1] C. WYTHE COOKE, U. S. Geological Survey.

In my recently published report on the geology of the Coastal Plain of South Carolina, the statement is made that late Pleistocene Pamlico time, during which the sea stood about 25 feet above its present level, was preceded by a time of lower sea level.[2] This statement was based on evidence that came chiefly from outside of South Carolina, for I had not seen a contact of the Pamlico formation with underlying beds within the State. Since that report went to press, the canal of the Intracoastal Waterway mentioned on page 125 has been completed through Horry County. The following instructive section on it yields evidence that corroborates that statement.

SECTION WEST OF THE RAILWAY BRIDGE ACROSS THE INTRACOASTAL WATERWAY 2½ MILES NORTHWEST OF MYRTLE BEACH, S. C.

	Feet
Pamlico formation:	
3. Fine leached marine sand including a few thin beds of clay in the middle part and merging upward into clayey loam	12
2. Fine sand loaded with sea shells, many of which have both valves in juxtaposition. The upper part contains many oysters	6
Horry clay:	
1. Very dark brown clay containing comminuted plant fragments and woody tissues and diatoms. Cypress stumps and knees are rooted at the top. Some of the stumps extend a few inches above the clay into the overlying shell bed. The top of the clay is perforated by tubular holes, presumably made by boring creatures. Covered by water at high tide	3

The presence of rooted tree stumps beneath a thick marine deposit that evidently accumulated in quiet water gives conclusive evidence that the sea stood lower on the land when they grew than in the immediately succeeding epoch.

The name Horry clay, here used for the first time, is proposed

[1] Published by permission of the Director of U. S. Geological Survey. Received October 6, 1936.

[2] COOKE C. W., U. S. Geol. Survey Bull 867: 157. 1936.

for bed 1. It is pronounced O-ree, with the accent on the last syllable, as in Horry County, S. C., from which it is adopted.

The Horry clay contains a large flora of diatoms. A small sample studied by Kenneth E. Lohman of the U. S. Geological Survey yielded the 53 species in the following list:

A—abundant; C—common; F—few; R—rare; *—now living in fresh or brackish water; species not preceded by an * are marine.

Melosira cf. *M. recedens* Schmidt (F), *M. sulcata* (Ehrenberg) Kützing (C), *Podosira stelliger* (Kützing) Mann (C), *Cyclotella striata* (Kützing) Grunow (F-C), *C. striata bipunctata* Fricke (F), *C.* sp. (F), *Coscinodiscus denarius* Schmidt (F), *C. excentricus* Ehrenberg (F), *C. nitidus* Gregory (F), *C. oculus-iridis* Ehrenberg (F), *C. radiatus* Ehrenberg (F), *Actinoptychus parvus* Mann (R), *A. splendens* (Shadbolt) Ralfs (R), *A. undulatus* Ehrenberg (F), *Polymyxus coronalis* Bailey (A), *Aulacodiscus argus* (Ehrenberg) Schmidt (F), *Eupodiscus* cf. *E. decrescens* Rattray (R), *Auliscus pruinosus* Bailey (R), *Actinocyclus ehrenbergii* Ralfs (F), *Triceratium favus* Ehrenberg (F), *T. reticulum* Ehrenberg (F), *Biddulphia* cf. *B. rhombus* (Ehrenberg) Wm. Smith (F), *B.* sp. (R), *Grammatophora* sp. (R), *Plagiogromma* sp. (R), *Rhaphoneis amphiceros* Grunow (C), *R. belgica* (R), *R.* aff. *R. angularis* Lohman (C), *R. surirella* Grunow (R), *Synedra investiens* Wm. Smith (R), *Leudugeria janischii* (Grunow) Van Heurck (R), **Eunotia monodon* Ehrenberg (R), *Cocconeis scutellum* Ehrenberg (R), **Diploneis elliptica* (Kützing) Cleve (R), *D. gründleri* (Schmidt) Cleve (R), *D. weissflogii* (Schmidt) Cleve (F), **Frickea lewisiana* (Greville) Heiden (R), *Trachyneis aspera* Ehrenberg (R), **Navicula peregrina* (Ehrenberg)Kützing (R), *N.* aff. *N. spectabilis* Gregory (R), *N.* sp. (R), **Caloneis formosa* (Gregory) Cleve (R), **Gyrosigma acuminatum* (Kützing) Rabenhorst (R), **G.* cf. *G. balticum* Ehrenberg (R), *G.* sp., *Pleurosigma* sp. (F), *Amphora pediculus* (Kützing) Grunow (R), **Epithemia zebra porcellus* (Kützing) Grunow (R), **E. zebra saxonica* (Kützing) Grunow (R), **Rhopalodia gibberula* (Ehrenberg) Müller (R), **Nitzchia granulata* Grunow (R), **N.* cf. *N. plana* Wm. Smith (R), **N. tryblionella* Hantzsch (R).

Mr. Lohman comments on this flora as follows:

"The facts that the fresh- and brackish-water species are all rare in the Horry clay and that the marine species are abundant indicate a marine to slightly brackish environment at the time of deposition, such as would be found in the seaward part of an estuary or bay beyond the influence of any major fresh-water stream that may have emptied into it. The most abundant species, *Polymyxus coronalis*, is now known to be living only in the tropics, and this is true also of several of the others, strongly suggesting that the Horry clay was deposited under conditions at least as warm, and most probably warmer, than those existing in the same region today.

"*Polymyxus coronalis* occurs abundantly in the Pleistocene beds penetrated by a well drilled at Wildwood, N.J., at a depth of 78–180 feet. It also occurs sparingly in the "blue clay" at Philadelphia, which represents its northernmost known occurrence. This species is extinct along the Atlantic coast of North America, and so far as known is living only off the mouths

of the Para and Amazon rivers. It has never been found in rocks older than Pleistocene. Another common species, *Triceratium favus*, has a known range of Pleistocene to Recent. Many other species in the assemblage also occur in Pleistocene beds in the Atlantic Coastal Plain, but most of them are long-ranging species having little significance for age determination."

The peaty appearance of the clay and the cypress stumps rooted in it would lead one to suppose that the clay had accumulated in a cypress swamp; but all the trees are rooted in the top of the deposit, and all the common species of diatoms are marine. It is therefore evident that the clay was deposited in salt water. Before the cypress trees could have taken root there must have been either a lowering of sea level or a freshening of the water due to other causes. The clay may represent the deposits of a salt marsh that eventually was changed into a fresh-water swamp by the building of barriers across the tidal inlets.

As the diatom flora includes several tropical species, it is hardly likely that the clay could have been deposited during a glacial stage. It more probably represents part of an interglacial stage, presumably the early part of that including Pamlico time, after sea level had risen from the low of the preceding glacial stage to approximately its present height but before it had attained its maximum of 25 feet above the present level. The trees may have grown in a flooded estuary freshened toward the end of a brief pause in the submergence.

Further flooding of the estuary in which the Horry clay was deposited widened it into a V-shaped bay opening towards the southwest. The bay was separated from the Atlantic Ocean by a low, narrow peninsula composed (at Myrtle Beach) of coarse reddish-brown sand containing disc-shaped, flat pebbles. In the "Geology of the Coastal Plain of South Carolina"[3] I interpreted this peninsula and the higher land across the bay as having been built above water by the waves and winds of Pamlico time. In the light of newer evidence it seems more likely that they are of Talbot age and that the Horry estuary occupied a valley in the Talbot plain.

A somewhat similar occurrence of diatomaceous clay and cypress stumps overlain by marine fossiliferous sand (Pamlico formation) is reported by Mansfield[4] on the Neuse River about 10 miles below New Bern, N. C. At this place, however, *Nitzschia scalaris*, a fresh-water species, predominates. The presence of at least two marine

[3] U. S. Geol. Survey Bull. **867**: 7, 153: pls. 1, 4, 17. 1936.
[4] MANSFIELD, W. C., U. S. Geol. Survey Prof. Paper **150**: 134. 1928.

species there indicates that the deposit was formed in an estuary to which salt water had occasional access. Although the incomplete list of the diatoms on the Neuse includes no species listed from the Horry clay near Myrtle Beach, the two deposits are probably contemporaneous, for both are estuarine, both underlie the marine Pamlico formation, and they stand at the same level. If they are contemporaneous, they yield further evidence that there has been no tilting of late Pleistocene deposits in the Carolinas.

The lower part of the Pamlico formation at the railroad bridge near Myrtle Beach (bed 2 of the section) is highly fossiliferous. Many of the fossils are well preserved and larger than the usual sizes that the same species attain along the Carolina coast today—an indication of warmer water. Among the organisms represented are unidentified corals; unusually large sand dollars (*Mellita quinquiesperforata*); and more than 60 species of mollusks, some of which (e.g. *Rangia cuneata*) no longer live in the Atlantic Ocean. For the identification of the mollusks listed below I am indebted to Dr. W. C. Mansfield. The collection is especially valuable because all of the specimens were found in place, without possibility of contamination from other beds. As many of the bivalves retain both shells in juxtaposition, it is unlikely that any of them were reworked.

Acetocina canaliculata (Say), *Terebra dislocata* (Say), *T. concava* (Say), *Mangelia cerina* Kurtz & Stimpson, *Marginella* sp. (immature), *Olivella nitidula* Dillwyn, *Oliva sayana* (Ravanel), *Busycon caricum* (Gmelin), *B. caniculatum* (Linnaeus), *Cantharus cancellaria* (Conrad), *Alectrion acuta* (Say), *A. trivittata* (Say), *Ilyanassa obsoleta* (Say), *Anachis avara* Say, *A. obesa* C. B. Adams, *Mitrella lunata* (Say), *Urosalpinx cinerius* (Say), *Odostomia* sp. *Turbonilla* sp., *Seila adamsii* (H. C. Lea), *Littorina irrorata* Say, *Crepidula fornicata* (Linnaeus), *C. fornicata ponderosa* H. C. Lea, *Polinices duplicatus* (Say), *Tectonica pusilla* (Say)?, *Sinum perspectivum* (Say), *Glycymeris* sp. (young), *Argina pexata* Say, *Arca transversa* Say, *Noetica ponderosa* Say, *Fossularca adamsi* Dall, *Ostrea virginica Gmelin, Pecten gibbus gibbus Linnaeus, Anomia simplex* d'Orbigny, *Modiolus* sp. (fragment), *Pandora trilineata* Say, *Venericardia tridentata* Say, *V. perplana* Conrad, *Phacoides mulrilineatus* Tuomey & Holmes, *P. radians* (Conrad), *P. trisculatus* Conrad, *Divaricella quadrisulcata* (d'Orbigny), *Rochefortia* sp., *Cardium muricatus* Linnaeus, *C. robustum* Solander, *Dosinia discus* Reeve, *Chione cancellata* (Linnaeus), *Venus mercenaria* Linnaeus, *Gemma purpurea* H. C. Lea?, *Tellina* sp. cf. *T. sayi* Deshayes, *Semele proficua* Poulteney, *Abra aequalis* (Say), *Donax variabilis* Say, *D.* sp., *Spisula similis* Say, *Mulinia lateralis* Say (very abundant), *Rangia cuneata* Gray, *Ervilia concentrica* Gould, *Corbula contracta* Say, *Barnea costata* Linnaeus.

The contact between beds 2 and 3 of the section near Myrtle Beach apparently marks the location of the top of the saturated

zone before the canal was dug. The absence of shells above this level may be attributed to the leaching action of rain water that, in percolating downward, dissolved the shells. The absence of shells from terrace deposits higher than the Pamlico has been advanced as an argument against the marine origin of the higher terraces; but most of the higher terrace deposits are porous and have been subjected to leaching for a longer time than the Pamlico formation.

The sequence of late Pleistocene events that can be inferred from the sections near Myrtle Beach, on Neuse River, and from other evidence is as follows: First, a lowering of sea level from the 42-foot Talbot stage to a depth estimated by Stearns[5] as about 60 feet below the present level; next, a rise of sea level to approximately its present position and deposition of the Horry clay in estuaries filling valleys cut in the Talbot terrace during the preceding epoch; then, continued rise of sea level to a height of 25 feet, expansion of the Horry estuaries, and deposition of the Pamlico formation; next, fall of sea level to a depth at least 25 feet lower than the present, indicated by submerged channels in Pamlico Sound and elsewhere; finally, rise of the sea to its present level, drowning the valleys and lowlands of the preceding epoch to form the existing sounds and estuaries.

I have elsewhere[6] tentatively correlated the Pamlico formation with the last major interglacial stage, commonly called Peorian—a correlation that seems to be confirmed by the studies of MacClintock and Richards.[7] The Horry clay apparently represents the early part of the same stage.

PALEONTOLOGY.—*Pliocene and Pleistocene mollusks from the Intracoastal Waterway in South Carolina.*[1] W. C. MANSFIELD and F. S. MACNEIL.

In June, 1935, and again in April, 1936, the writers visited the Intracoastal Waterway at North Dam (Location Contract 195) about 3 miles west-southwest of Little River and about 15 miles northeast of Myrtle Beach, S. C. The canal here traverses a low plain, which as interpreted by Cooke,[2] is the southward continua-

[5] STEARNS, H. T., Geol. Soc. Am. Bull. **46**: 1941. 1935.

[6] COOKE, C. W. *Tentative ages of Pleistocene shore lines.* This JOURNAL **25**: 333. 1935.

[7] MACCLINTOCK, PAUL, and RICHARDS, H. G. *Correlation of late Pleistocene marine and glacial deposits of New Jersey and New York.* Geol. Soc. Am. Bull. **47**: 317. 1936.

[1] Published by permission of the Director, U. S. Geological Survey. Received October 12, 1936.

[2] COOKE, C. W. *Geology of the Coastal Plain of South Carolina.* U. S. Geol. Survey Bull. **867**: 125–126. 1936.